HYDROGEN PRODUCTION FROM SOLAR TRACKER WITH MPPT TECHNIQUE IN SEAWATER ELECTROLYSIS

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Abstract: The future fuel hydrogen is being produced by doing electrolysis in seawater. The power for electrolysis is given by using solar panel. The electrode used for seawater electrolysis is being coated with various layers. The layers used are Nickel iron hydroxide and Nickel sulfide layers. These layers will protect the electrode from corrosion. The maximum power point tracking technique is deployed in order to utilize the most power from the photovoltaic panel. This is done with the help of light dependent resistors or photo resistors, micro controller Arduino and servo motor of 6V. The switching operation was done along with Node MCU and an ESP8266 Wi-Fi module. The objective of this project is to produce hydrogen for industrial use. The 12V solar panel is used for providing power for electrolysis process. One form of energy is converted to another form efficiently without loss. The energy from the Sun is converted to hydrogen for industrial use or for running vehicles. The current density should be high for such usage. Several tests are performed to show the variations in hydrogen production, with and without layer coating, with and without solar tracking technique. The tests include variations in solar irradiance, variations in anode, stability test and efficiency chart. The variations in solar intensity radiation were measured with the help of pyranometer.

Keywords: Solar Panel, Servomotor, LED Load, Electrolysis

I. INTRODUCTION

Production of hydrogen fuel by electrolysis of water will be an impressive way for storing renewable energy .The process of water splitting into hydrogen and oxygen is not entirely new. This already exists, and the process is known as electrolysis of water [1]. And where the change comes is, instead of fresh drinking water, seawater is used for this purpose. The usage of seawater that is the salt water for splitting using electrolysis process with the current technology leads to the damage of the device itself. To avoid this damage, expensive desalination of seawater is needed before electrolysis. Or else the entire technology has to be changed to avoid damage of the device [2]. Previous studies conducted on this basis, was mainly focused on fresh water electrolysis. But this will lead to scarcity in fresh drinking water sources. To avoid this scarcity issue, the use of seawater which is abundant in nature, will be a clear solution. When seawater is used, again another issue arises. Corrosion on the electrode is the issue. So in order to

prevent corrosion, the electrodes used for electrolysis are given with coating. Thus it will resist corrosion and thus the life span of the electrode will also increase [3].

Existing water splitting methods use precious highly purified water because the negatively charged chloride content in seawater will corrode the anode, thus limiting the life span of the system [4]. In splitting water into hydrogen and oxygen, the positive end that is the anode will produce breathable oxygen and the negative end that is the cathode will emit hydrogen. If the anode is coated with layers that are rich in negative charges, the layers will repel the chloride content and thus slows down the decay of underlying metal. Here nickel iron hydroxide layer can be mounted on nickel sulphide layer which is being formed on nickel foam core. Nickel iron hydroxide sparks the electrolysis [5][6]. The nickel sulphide layer evolves into a negatively charged layer. And this layer will protect the anode by repelling the chloride content in seawater. It is found that without these layers the system works for only twelve hours. And with these layers it will work for more than thousand hours [8]. Since corrosion occurs at high current, all electrolysis is done at lower current and there by the production was found to be slow. But this new approach will help to make the system work at normal current without causing damage [10].

II. OBJECTIVES OF THIS RESEARCH

The objectives of this project are:

- Production of Hydrogen from seawater electrolysis using energy absorbed from the Sun.
- Switching the power from solar panel and AC mains for driving electrolysis.
- Producing Hydrogen for industrial usage with high current density.

III. METHODOLOGY (SOLAR TRACKING SYSTEMS)

The use of fossil fuel is increasing day by day and at the same time its depleting as it is not available in sufficient amount. Now it is the time to find an alternative source which full-fills the demand of consumers [11]. The source of energy that never depletes or the one which is renewable and clean should be found out. According to Energy Policy Act of 1992, Hydrogen is considered as an alternative fuel. When hydrogen fuel production is taken into account, it is found to be in its infant stage. Hydrogen can be produced through several sources. This can be generated from natural gas, coal, oil, and water [12]. When hydrogen production from fossil fuels is taken into account, it will have to go through different processes like coal gasification, steam reforming and so on. Apart from fossil fuel, the only source for producing hydrogen is water. But water is very precious in our life, especially pure drinking water source. The challenge is to produce hydrogen in an effective manner for securing our future generation. The scope of hydrogen powered vehicles is very high.

Foreign countries are experimenting and implementing this technology to avoid the use of other fuels available, which is found to be in a limited amount [14]. The fossil fuels are having transportation criteria, drilling, mining, and many other procedures. The energy should be consumed in a right manner from the

environment and there comes a need to set a limit in using the sources available from our natural environment.

A way to slow the use of fossil fuel is to find an alternative that fulfils the need of fossil fuel. It is natural that, this task is not easy. Switching over to a fuel apart from fossil fuel will not be accepted initially by the crowd. But this is the solution which seems better. Hydrogen can be produced in many ways, but all of them end in high cost. The cheapest way of producing hydrogen with good efficiency should be found out. The electrolysis of water seems to be the ancient way in producing hydrogen [15]. As fresh water is facing scarcity, another source of water, which is the sea water that is found to be abundant in our nature is being used. In order to avoid the corrosion problem, special coating is provided for the anode and cathode. The power for functioning of electrolysis can be provided by the renewable energy sources, that is, from solar and also from AC load [16]. The advantages of hydrogen are found to be as less greenhouse gas production, as it doesn't produce any carbon dioxide during combustion. The energy converted will be environmental friendly.

Figure 1 shows the block diagram of seawater electrolysis. There are six blocks namely solar panel, anode, cathode, electrolysis chamber, oxygen and hydrogen. Here the solar panel provides the power needed for electrolysis process. This photovoltaic panel is connected to the electrolysis chamber for further reaction to take place [18]. In the electrolysis chamber, there is a anode and cathode. The anode is coated with nickel Iron hydroxide electro catalyst layer which is formed on nickel sulphide layer, that is being mounted on Nickel substrate or Nickel foam. And the cathode is being protected by further protective layers like Nickel chromium combinations. The anode is covered by layers that are rich in negative charges [15] [19].

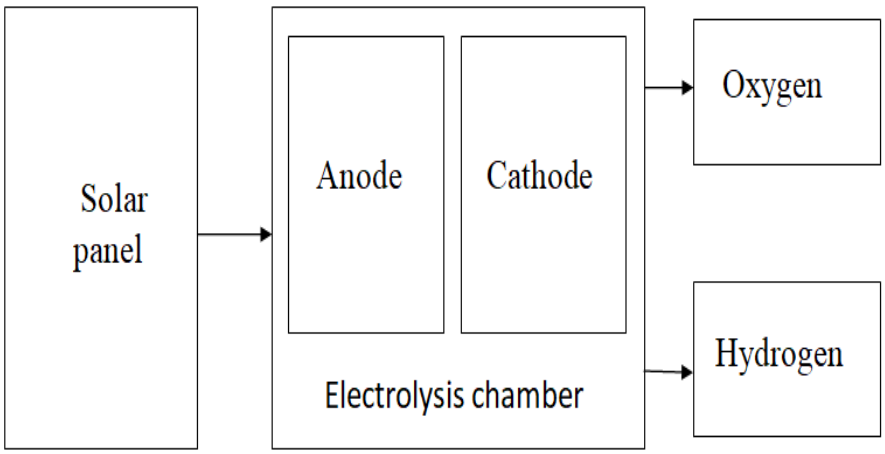

Fig. 1 Block Diagram of Electrolysis

This is because, layers will repel the chloride content found in salt water. In two magnets, the negative end pushes against one another, similarly chloride will be repelled by the negatively charged layer. And there by slows down the decay of the underlying metal. The nickel Iron hydroxide sparks the electrolysis and nickel sulphide evolves into a negatively charged layer that protects the anode by repelling the chloride. The breathable oxygen will be expelled out from the anode and cathode produces the hydrogen. The studies conducted earlier showed that, due to corrosion at higher current, seawater splitting for hydrogen fuel had run only small amount of electric current. While using this device, about ten times

more electricity will be conducted, thus hydrogen will be generated from seawater at a faster rate. In seawater the anode works only for about twelve hours without this negatively charged coating. While, with the layer protection it will be able to work for more than a thousand hours. The system can operate at electric current which is same as that used in industry today.

Figure 2 shows the block diagram of solar tracking section. There are six blocks in this block diagram namely, LDR1,LDR2, power supply, Arduino, servo motor and solar panel. Both the light dependent resistors are connected to the Arduino board. Along with that the servo motor is also connected to the Arduino board. The micro controller is supplied with 5 V. The light dependent resistors are connected to this 5-volt supply. The solar panel will start to rotate to one side when the first Light Dependent Resistor is flashed with light. The solar panel will start to rotate in opposite side when the second Light Dependent Resistor is flashed with light. The main concept of this solar tracking system is that, during the sunrise the solar panel will be exactly facing towards the sun and in the evening, solar panel will be exactly at 90 degrees. When sun sets the solar panel again rotates towards the sun. The solar energy is fully extracted without any wastage. The power supply is given to Arduino board and the servomotor rotates accordingly.

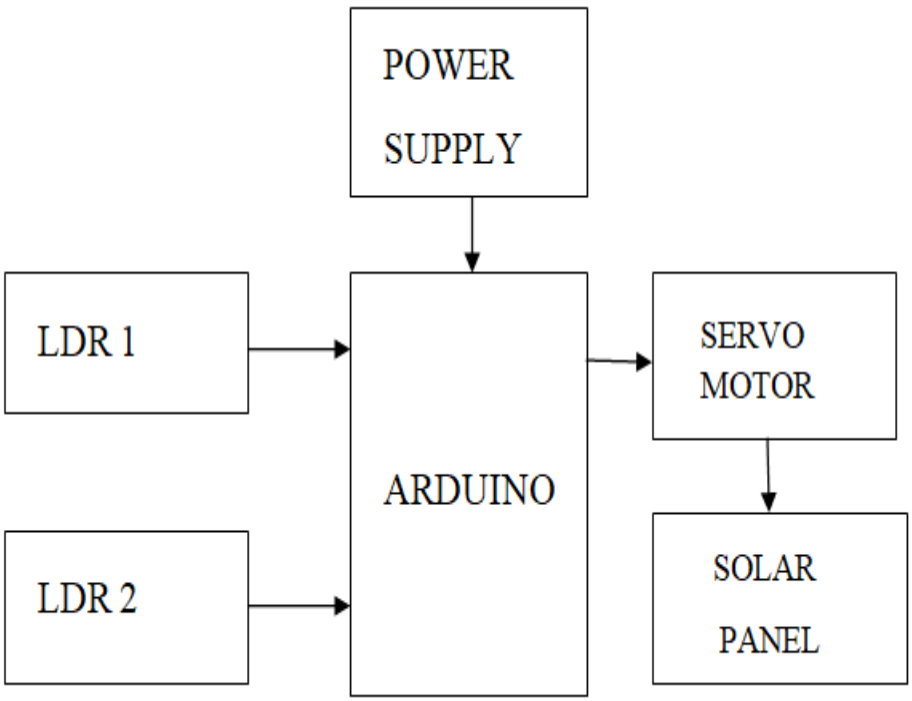

Fig. 2 Block Diagram of Solar Tracking Section

Figure 3 shows the block diagram of the control system. There are a total of six blocks in this block diagram namely solar energy, op-amp1, op-amp2, AC load, ESP8266, Load(Light Emitting Diode). The solar energy from the sun is absorbed by the solar panel and is connected to op-amp 1. Op-amp1 is directly connected to the load (light emitting diode).Solar energy and AC load can be switched using this control system.

The energy consumed for this purpose is not wasted by any means. The AC load is connected to the op-amp2 which is then connected to the load (light emitting diode). From the Wi-Fi module there are two connections. One connection is to op-amp1 and another is to op-amp2. This control system is used for controlling the power manually through our hands by using a smart phone. The main role of this system is switching the solar energy and AC load through our hand set. The AC load is used whenever solar energy is not available.

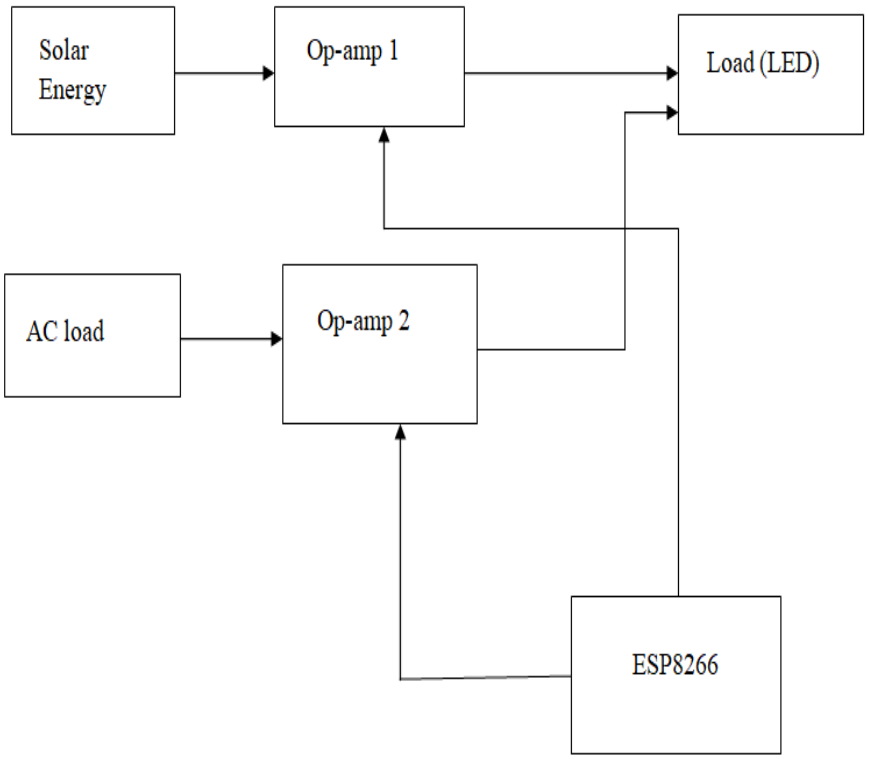

Fig.3 Block Diagram of Control System

IV. HARDWARE DESCRIPTION

Electrolysis is the process of splitting water into two components, that is, hydrogen and oxygen with the help of electricity. This involves the connection of power source to two electrodes dipped in water. When the power is turned on, hydrogen gas is evolved from the negative end (cathode) and breathable oxygen is evolved from the positive end (anode). The need of components is prominent for completing any system. The main components used for setting up this project are explained below.

A. Solar Panel

Solar panel is the component which converts the energy from sun to electricity. The solar panel is also known as photovoltaic panel or module. The solar panel is available in various sizes. The size of the panel depends on its use.

Fig. 4 Solar Panel

Figure 4 shows the diagram of solar panel. The solar panel can be used for residential purposes and for industrial purposes too. Basically the use of solar energy is increasing day by day. Large and wide solar panels are used in airports, buildings, houses, industries, colleges, parks and so on. Small solar panels are also available in market. The small photovoltaic modules are used for project purposes in colleges, for running single applications like fan.

B. Electrode

The electrode has many uses in chemical industry. Basically an electrode can be an anode or cathode.

Fig. 5 Electrode

Figure 5 shows the schematic diagram of an electrode, and it can be an anode or cathode. If the electrode has got negative charge, then it is named as cathode and it is indicated by negative sign (-). This can be used for electrolysis, and here in this system both anode and cathode is used for producing hydrogen and oxygen from electrolysis.

C. Electrolysis

Electrolysis is the process of splitting of water in to two components, namely, oxygen and hydrogen with the help of electricity. This process thus involves the connection of power source to two electrodes dipped in water. When

the power flows through the electrolysis chamber, the cathode or the negative end will emit hydrogen and the positive end or anode will emit oxygen simultaneously.

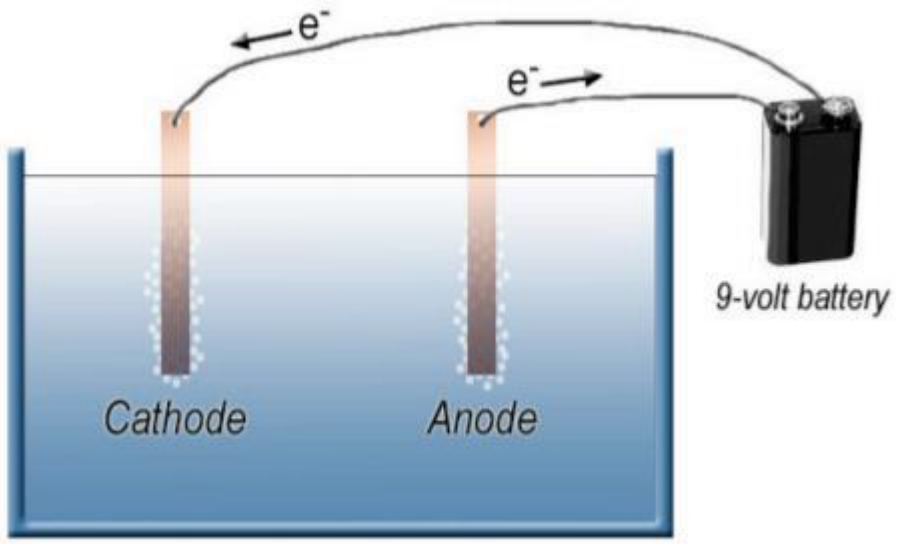

Fig. 6 Electrolysis Process

Figure 6 shows the diagrammatical representation of electrolysis process. As shown in the figure, there is a negative end which is known as the cathode. There is another electrode anode, which is also known as the positive end of the electrolysis process. A 12 V battery is connected to it for providing power for electrolysis process. Electrolysis can be done using both seawater and pure water.

D. Battery

Batteries are basically of two main types, one is rechargeable and another is nonrechargeable. Rechargeable batteries can be used and recharged when the power available comes down in it. A Li-ion rechargeable battery of rated capacity is used here. The nominal voltage of this battery is 3.7V and standard charging time is approximately 4 hours.

Figure 7 shows the diagram of rechargeable battery. As the name suggests, it can be charged and reused. While, non-rechargeable battery can be used only once, after that, it becomes disposable. Non-rechargeable battery will be of small size, and some rechargeable batteries of small size are now available in market. The difference in rates of rechargeable batteries can be found. It will be of high rate, but it is non- disposable and rechargeable, so high initial cost can be ignored. Though non- rechargeable batteries are of low cost and small size, when the usage of the product is taken in to account, rechargeable one is far better than the non-rechargeable battery.

Fig. 7 Battery

E. Ardunio Board

Figure 8 shows the diagram of Arduino board. Atmega328P is the microcontroller used in this Arduino. It is an 8 bit AVR microcontroller. The operating voltage of the board is 5V. Crystal oscillator, serial communication ports and voltage regulator is also provided in the board to support the microcontroller. Arduino board is considered to be an open-source hardware. Most of the projects in colleges are concentrated on Arduino based ones. The use of Arduino in this system is the setting of program for rotating the solar panel using servo motor.

Fig. 8 Arduino Board

F. Servomotor

Figure 9 shows the schematic diagram of servo motor. Servo motor has got many applications, like it is used in robotics, CNC machines or automated manufacturing. The input signal given for a servo motor will be in analog or digital form. This input signal will be based on position of the sun. Servo motors can be used as an alternative to stepper motors under some given conditions. The size of servo motor varies with rate, for tracking only small sized servo motor is need

Fig. 9 ***Servo Motor***

V. HARDWARE IMPLEMENTATION

The system deals with an innovative way of splitting hydrogen and oxygen from seawater through electricity. The methods that existed focus on splitting of purified water. But water is a precious resource and is expensive to produce.

A. Circuit Diagram

The electricity used for the working of electrolysis process can be switched using a handset.

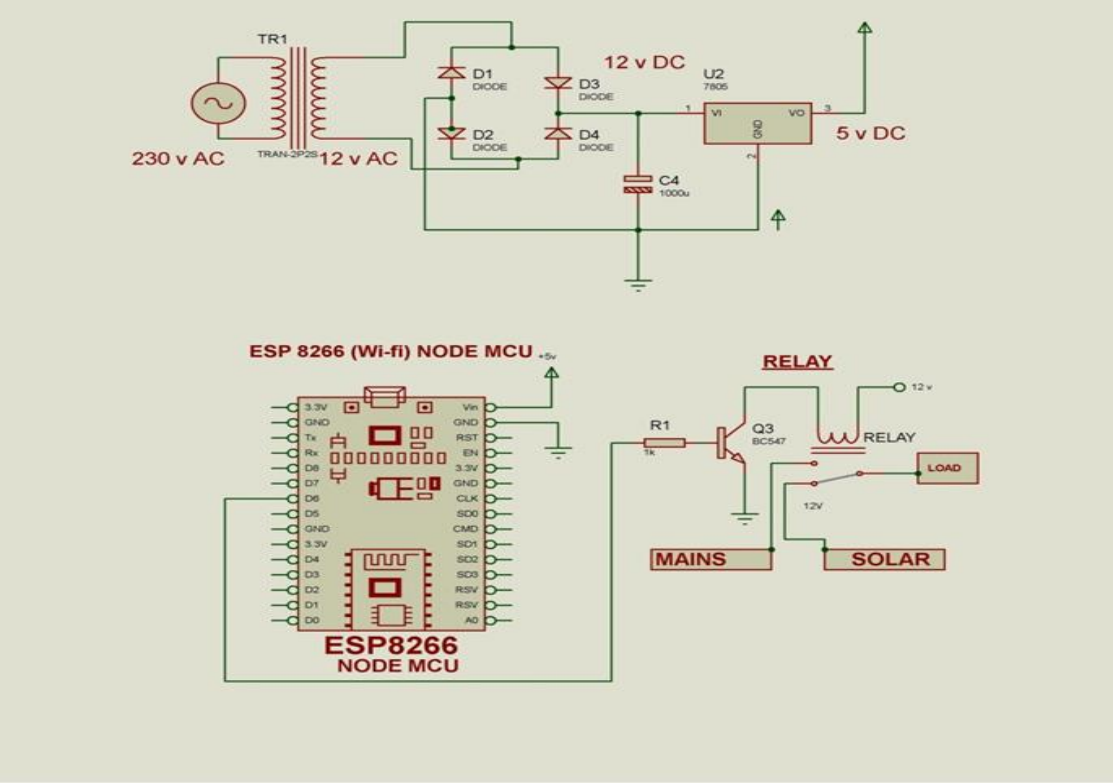

Fig. 10 Circuit Diagram of Switching Unit

The sunlight that strikes the panel is converted to electrical signal. The output from solar panel and mains are given to the relay. Based on the priority, switching operation is done using relay. The process is controlled using Node MCU. The data is stored in cloud using Wi-Fi module and is connected to a smart phone via hotspot. Figure 10 shows the circuit diagram of a switching unit used in the project. The switching is done through the smart phone. An external power supply is given to Node MCU.The 230V AC supply is given to a step down transformer. Transformer will step down the voltage into 12V AC. A bridge rectifier is used for the rectification purpose which will convert 12V AC into 12V DC supply. A filter capacitor is connected at the output of the rectifier for removing the ripples. IC 7805 voltage regulator is used for producing 5V DC which is the operating voltage of the controller. For this a Wi-Fi module, node MCU and relay unit are used. The node MCU is a transformed version, which is believed to be the integral part of this circuit diagram.

B. Experimental Set Up

A 12 V solar panel is used in this project for driving electrolysis process. When hydrogen is burnt it doesn't emit carbon dioxide, instead produces only water as its by product. Thus problems related to climate change issues can be eliminated. The power source will be connected to two electrodes dipped in water for electrolysis. When the power is applied, the hydrogen gas will be expelling out from the negative end, that is, from the cathode side. While the positive end, namely anode, will start to emit breathable oxygen simultaneously. The issue is that, the positive end will be corroded by the negatively charged chloride present in seawater salt, which limits the life span of the system. When the anode is coated with negatively charged layers, it will be repelling the chloride content and decaying of the underlying metal can be slowed down. Nickel iron hydroxide will be layered on top of nickel sulphide, which covers the nickel foam core. The nickel foam will be acting as a conductor. From the power source electricity will be given and the electrolysis will be sparked by the nickel iron hydroxide. Thus it will separate the hydrogen and oxygen from water. The nickel sulphide will be evolving into a negatively charged layer during electrolysis and this layer will be protecting the anode. The power for working of this system will be given by solar energy.

Fig. 11 Experimental Set Up of Electrolysis Process

A battery can be used to store the solar energy when power is excess and can be utilized when power is not available. During day time, the power will be sufficient enough to fulfil the demand. But during night time, when there is no sunlight, the stored energy can be utilized. During the rainy season, the availability of energy will be less. The energy that is being stored in the battery can be utilized. For this switching operation is installed in this system for switching the power from solar panel and battery as depicted in figure 11.

Figure 12 shows the electrical circuit model of control system used in this project. This system is used for controlling the solar energy coming from the sun. Two PN junction diodes are used. These diodes are then directly connected to the output. The power supply to one IC is given by the solar panel and the power supply for next IC will be given by the AC mains.

Fig. 12 Electrical Circuit Model of Control System

The experimental set up of the control system or switching system was easy to build up. The battery was connected in it to provide power when the power from solar panel is not available. The battery that is being used for this project is rechargeable battery. So whenever the charge reduces in the battery, it can be recharged and there is no need of disposing it. Figure 13 shows the hardware of switching system. The switching of energy from solar panel and AC mains is done. According to the availability of power the switching operation is done. Along with battery the solar panel and the control board can also be seen in the figure 13.The control system switches the power according to availability and this switching operation can be done manually and also through handset with the help of Wi-Fi module, Node MCU and other components.

VI. RESULT AND DISCUSSION

Hydrogen production is dependent on solar energy availability and electrolysis experiment. The protection of anode will increase the life line of this project. The tests on this project were conducted on the months of March and April. The availability of solar energy during that time was quite good.The experiment was conducted for two different cases: with layer protection and without layer protection.The current density variations with respect to potential (v) by providing layer protection and without layer protection were taken in to account. The experiments were conducted on days within a week of April. The stability in production of hydrogen is tested and was represented graphically. The variation of stability in hydrogen production was noticed with respect to time in

hourly basis by plotting graphs. The efficiency of hydrogen that was produced was checked and this was done with respect to current density. Thus, the following graphs were plotted: a. Current Density Vs Potential, b. Stability Test, and c. Efficiency Vs Current density

A. Variations of Anode

The current density and potential (v) are two important parameters that are dependent on hydrogen production and those are clearly focused by plotting graphs. Figure 14 shows the variations of anode before and after activation in the solution. The solution used is being mixed with KOH and Na-Cl. Here the graph is being plotted between current density and potential. The graph clearly shows the variations before and after activation with the KOH and Na-Cl.

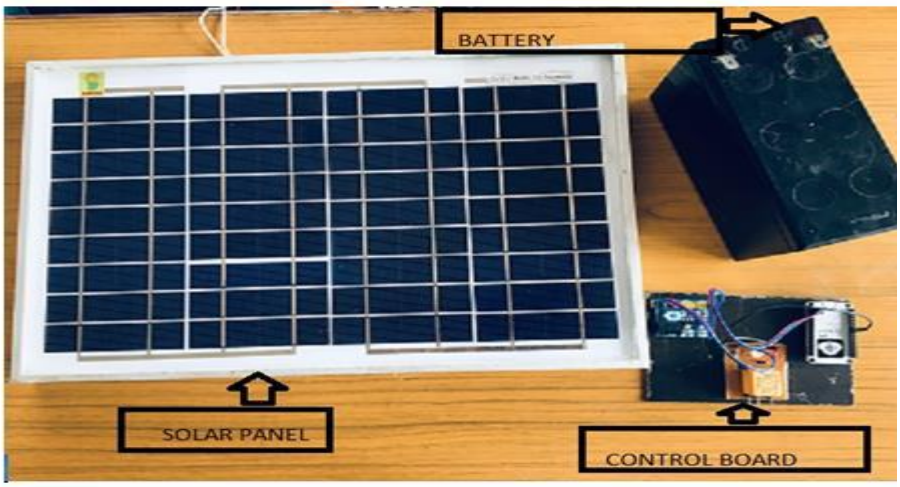

Fig. 13 Hardware of Switching System

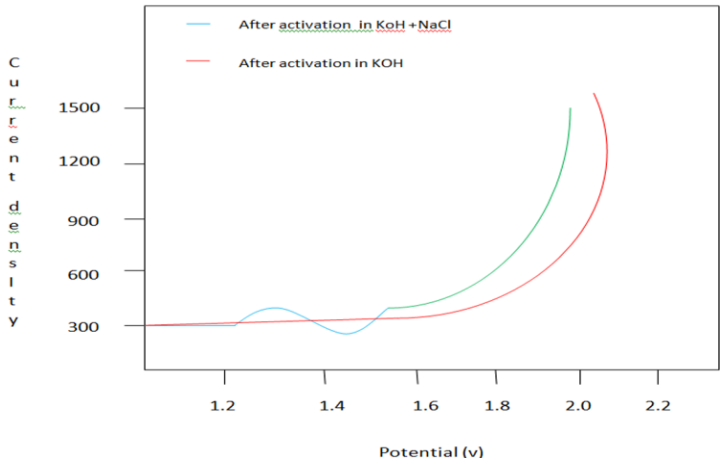

Fig. 14 Variations of Anode

The red coloured line in the graph shows the variations after the activation of KOH alone. And the blue coloured line in the graph shows the variations after the activation of both KOH and Na-Cl.

B. Stability Test

Stability test includes the identification of variations found in current density and temperature with respect to time. Here hourly time variation is chosen for identifying the variations and thereby the stability can be realised.

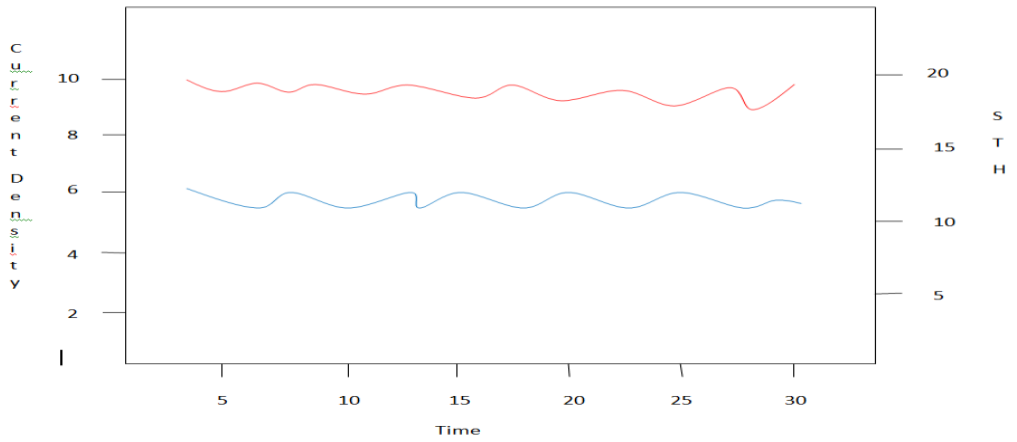

Fig.15 Stability Test

Figure 15 shows the stability test result which was conducted for twenty hours. The test was conducted for the solar cell based seawater electrolysis. And it was found that it stays stable throughout the hours. Here the graph includes X ,Y and Z axis. The X axis shows the time in hours, Y axis represents current density variations in mA/cm2 and finally the Z axis represents Solar to hydrogen efficiency.

C. Efficiency Chart

The parameters that are included to plot the graph for efficiency are Faradaic efficiency and current density. This is represented in the form of bars in the graph as shown below. The current density variations are given with a difference of 400 mA/cm2.

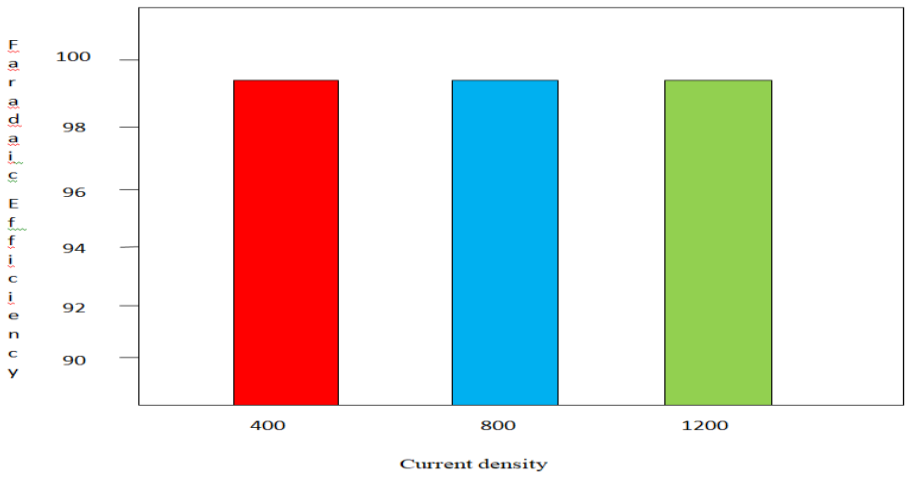

Fig. 16 Efficiency Chart

Figure 16 shows the efficiency chart . Here the current density is plotted in X axis and in the Y axis faradaic efficiency is plotted. The red coloured bar shows the current density at 400 mA/cm2. The blue coloured bar shows the current density at 800 mA/cm2 and green coloured bar shows the current density at 1200 mA/cm2.A tabular representation of variations in solar intensity is shown in Table 1. The solar radiation is calculated and noted from different location. First location is canteen area , from 2:00 pm to 2:15 pm the solar radiation average is calculated as 874.5 W/m2. Similarly readings were taken from various parts of college. The experiment was done with the help of Pyranometer device for measuring the solar irradiance.

TABLE. 1 Variations in Solar Intensity

LOCATION	TIME (PM)	SOLAR RADIATION (W/m2)	AVERAGE (W/m2)
Canteen	2:00 2:05 2:10 2:15	880 873 856 889	874.5
Infront of library	2:20 2:25 2:30 2:35	849 828 850 800	831.75
Aryabhatta	2:13 2:18 2:23 2:28	768 813 781 790	788
Workshop block	2:40 2:45 2:50 2:55	769 723 801 709	750.5
Administrative office	03:05 03:10 03:15 03:20	729 745 719 706	724.75

The variations in solar radiations are calculated within specified time intervals as explained above. The average of solar radiation at each location was found out. And it is found high at Canteen and low solar radiation average was found at administrative office. And thus it is depicted in a table format.

VI. CONCLUSION

The objective of this project is to produce hydrogen from solar energy based seawater electrolysis. The solar energy from the sun is permitted for tracking and most of the renewable energy is utilized. A code has been set for switching the energy from solar directly and the energy which is stored in battery. This project will surely help in building a hydrogen economy. Moreover, it will give a clear idea about the uses of hydro gen which still seems faded for people. This project concludes with an idea of using the renewable energy that is found abundant around us and not to be very much dependent on non-renewable energy which does not favour our environment.

Our country is planning to replace fossil fuel with Hydrogen fuel in vehicles. In order to become this possible, the source for producing hydrogen should be found. This project deals with an idea of producing hydrogen from seawater electrolysis. The energy utilized for running this process is solar energy. The solar energy is tracked using MPPT technique. The switching of energy by Wi-Fi module is also found in it. The future scope of this project is that, it will help in exposing a way for building hydrogen economy. The uses of fossil fuels can be minimized. The most common problem that people face today is the climate change issues, as hydrogen doesn't produce any green house gases, it will mitigate climate change issues.

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